# DSET Application Case Study: Snowpack Analysis

Please refer to the primary User Guide document for a general overview of the Navajo Nation Drought Severity Evaluation Tool (DSET) and a complete list of case study examples (including drought, agriculture, wildfires and meadows, and downloading data). If you are only interested in the snowpack case-study example, you can use this document.

## Introduction

Snowpack accumulation in mountainous regions is important for water resources. Snowpack on the Navajo Nation melts into streams to support vegetation and wildlife. Given the importance of precipitation in this semi-arid to arid landscape, drought conditions and a changing climate are a concern to the Navajo Nation. One impact of declines in precipitation and long-term drought is desertification. Desertification is a result of land degradation or destruction of topsoil where fertile landcover is destroyed by human activity (e.g. overgrazing) and natural destruction (e.g. drought). When a vast area of desertification occurs, resultant dust deposited on snow can increase snowpack melting rates. As a prominent snow accumulation area on the Navajo Nation, the Chuska Mountains will provide a meaningful analysis for snowpack development during the winter months.

There are two snow measurements that will be included in this analysis to understand the snowpack trends on the Navajo Nation. The first snow measurement is the Snow Water Equivalent (SWE), which is a function of the snow depth and the grain size. Ultimately, it is a measurement of the total volume of liquid water contained within the snow. Most often, snow depth is of interest to measure winter precipitation. However, the SWE value is needed to calculate the snow depth. The equation for snow depth is (SWE)/(Density) = Snow Depth. The density of snow is increased by packing, melting, gravitation, and recrystallizing. The Normalized Difference Snow Index (NDSI) provides the estimation of the snow covered area. Snow is highly reflective in visible wavelengths and has low reflectance in the shortwave infrared wavelengths, thus this ratio can be used to map snow and differentiate snow from clouds. NDSI values are used to estimate snow cover area, values of ~0.5 to 1 indicate snow cover.

## Components of Analysis
- Datasets: Sentinel 2 Top Of Atmosphere and SNODAS - Daily
- Variables: Normalized Difference Snow Index (NDSI) and Snow Water Equivalent (SWE)

## Objectives
- Use the Sentinel 2 TOA dataset to create a map of the NDSI values for the Navajo Nation for the past 16 years covering the years 2004 – 2020.
- Use the Sentinel 2 TOA dataset to create a map of the NDSI values for the Chuska Mountains for the Last December, January, February (Last DJF) time period (2019 – 2020).
- Create a time series of SWE and NDSI values for Chuska Mountains for the Last December, January, February (DJF) time period (2019 – 2020).

## Helpful Tips
- DSET is optimized for Google Chrome, please use Chrome.
- Faster networks are preferred when using DSET.
- Zoom to area of interest before submitting map requests to help with re-computing data.
- Resubmission and reset of DSET can help with fail requests that produce a server error.
- The figures included in this case study will help you navigate the DSET to locate the features associated with each step. It is suggested that you use the figure to ensure your selections are correct prior to completing each major step within the exercise.
- In the case study exercise, a color-coding system is used to help with navigation of the DSET features. For example, the section heading **Visualization Layer**, matches the color of the wording you will find on the DSET webpage.

Estimated Time for Completion for the Drought Case Study:  **16 Minutes**

This exercise for Case Study 4: Snowpack is broken up into two parts. The first part will specifically focus on NDSI values for the Navajo Nation and the Chuska Mountains for a 16-year time period, and then an evaluation of NDSI values for the Last DJF. The second part of this case study will focus on developing a time series for multiple variables for the Last DJF within the Chuska Mountains. Part 2 of this case study will center around the interpretation of SWE and NDSI values.

## Part 1: Snowpack Analysis

- Objective: Develop an NDSI analysis for short term and long-term snowpack. A time period of 16-years will show the NDSI values for the entire Navajo Nation. A three-month time period will be used to evaluate NDSI values for the Chuska Mountains.

The intensity of the snowpack created by winter snowstorms on the Navajo Nation will indicate the impact wintertime precipitation can have on drought conditions. The Chuska Mountains are a single mountain range that has the highest rates of snowpack accumulation on the Navajo Nation.
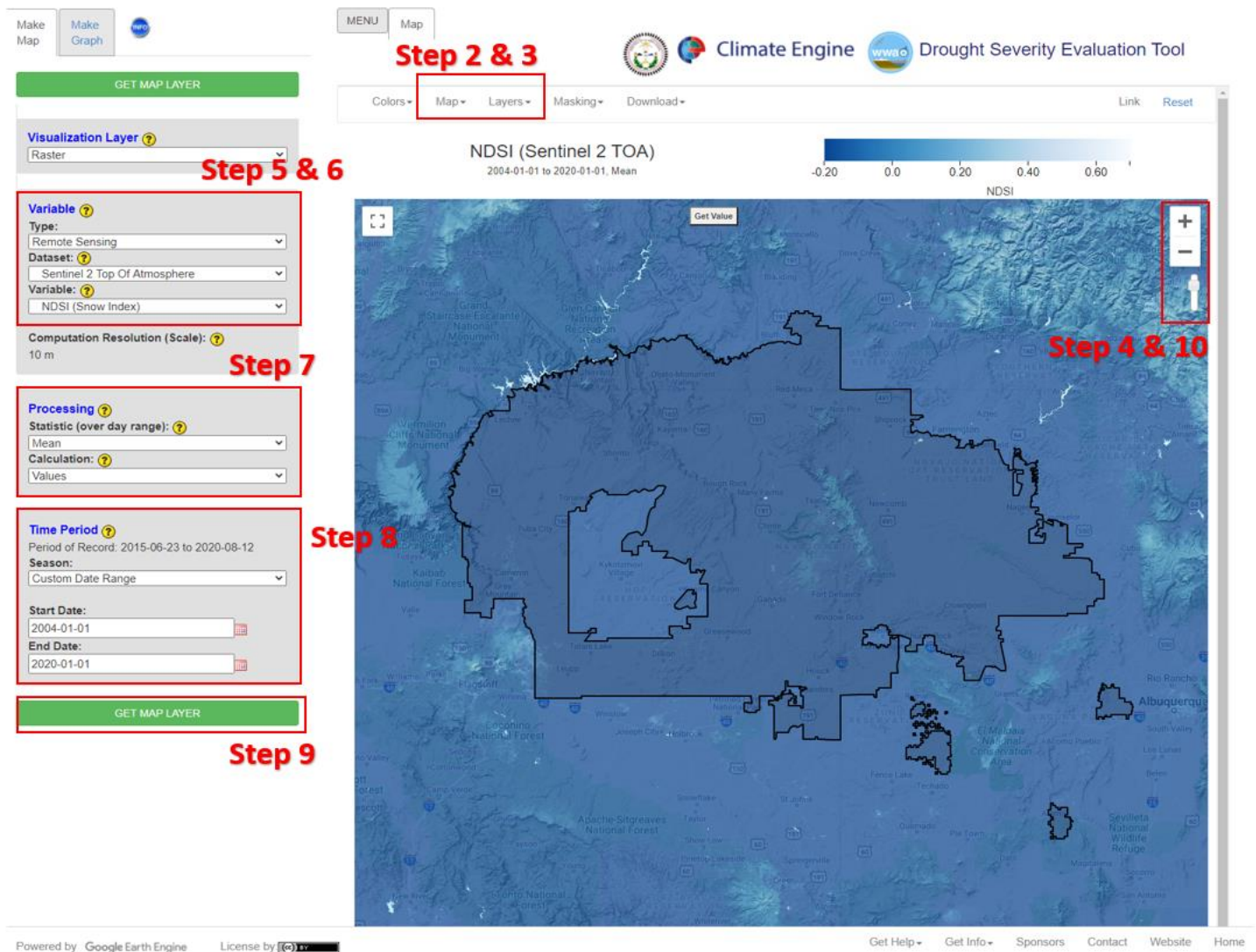


Figure 1. NDSI values using the Sentinel 2 TOA dataset are displayed in this figure for the entire Navajo Nation from 2004 - 2020. The NDSI values appear to show extremely low snow levels. The mountain ranges on the Navajo Nation appear to have slightly increased NDSI value. Guidance for DSET feature location are included for Steps 2-10.

1. Go to the DSET website using this link https://app.climateengine.org/dset.
   a. If you are conducting this Case Study for Snowpack Analysis after working on previous case studies, at the top right corner of the map, click **Reset**.
2. Under the **Layers** tab along the top, select the **Navajo Nation Boundary** and deselect the Navajo Nation Chapters.
   a. Note: The Navajo Nation Chapter boundaries will appear as the default, but for this exercise we will be looking at the Navajo Nation as a whole.
3. Click on the **Map** tab along the top, which hosts the map options, and select the **Terrain map**.
4. Zoom into the **Navajo Nation Boundary** using the "+" sign along the top right. Bring the reservation boundary to center map.
5. Located on the Make Map panel on the left side of the webpage, under the **Variable** section select the **Type** parameter to be **Remote Sensing**, and change the **Dataset** parameter to **Sentinel 2 Top Of Atmosphere.**
6. For the **Variable** select **NDSI (Snow Index)** located under the **Snow Indices section.**
7. Under the **Processing** section select the **Statistic (over day range)** to be **Mean**, leave the **Calculation** to be set on **Values**.
8. Under the **Time Period** section located on the same panel, select the **Custom Date Range.**
   a. Selecting **Custom Date Range** will change the **Start Date** and **End Date** options. For the **Start Date** enter **2004-01-01** and for the **End Date** enter **2020-01-01**.
9. Click on **Get Map Layer**, wait for the map to load. The loading of the map may take a few minutes for the request to process.
10. Once the processing is complete, the map will automatically display the data. The **transparency** may be decreased or enhanced to better see the results. On the top right of the map, move the opacity slider  down to 70% Opaque.
11. Your map should look like Figure 1 (above).

The NDSI values that indicate the estimation of snow covered area for the past 16-years have been minimal. The majority of the Navajo Nation has values of less than 0.20 on the NDSI scale (Figure 1). The minimal snow cover estimation provided through the NDSI values indicate the consistent drought conditions impacting precipitation activity year-round. In Figure 1, the Chuska Mountains shows the greatest NDSI values over the 16-

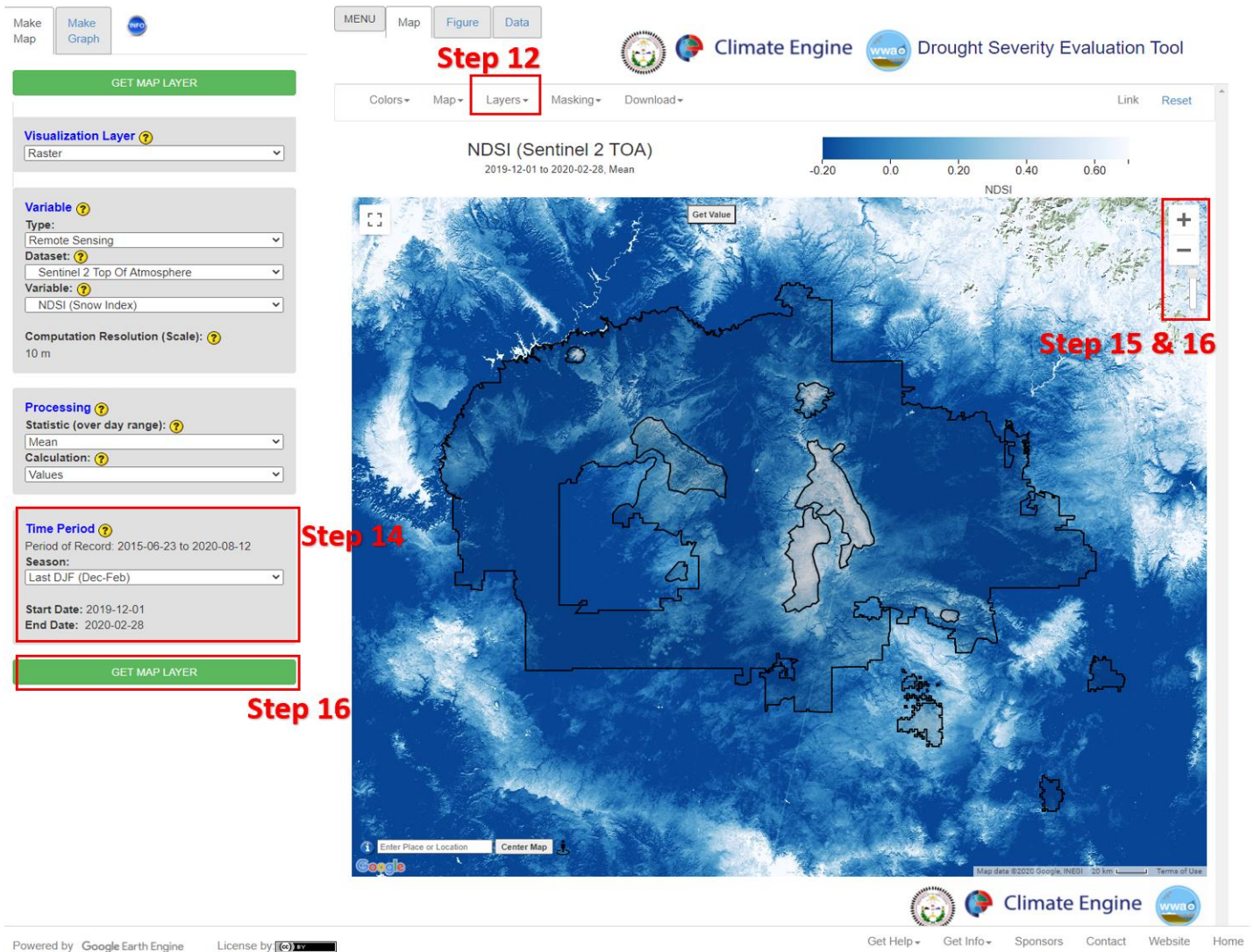year period. The next few steps will look deeper into the NDSI specially for the Chuska Mountains.



Figure 2. NDSI values for the Last DJF (2019-2020) for the Navajo Nation. The red box in the middle of the Navajo Nation encompasses the Chuska Mountains. This region generally has the highest NDSI values.. Included on this figure are Steps 12 -16 that locate DSET features to help navigate the tool to complete this case study.

12. Under the **Layers** tab along the top, the **Navajo Nation Boundary** should already be on your map now add the **Navajo Nation Mountain Ranges** to be displayed on the map.
13. Leave all the input parameters the same as you entered for Steps 1-7.
14. Under the **Time Period** section located on the same panel, select the **Last DJF (Dec-Feb).**
    a. Selecting the **Last DJF (Dec-Feb)** will change the **Start Date** to **2019-12-01** and end date to **2020-02-28**. Depending on the year of analysis the year will change. For example, if this exercise is done in the year 2022, the Last

DJF (Dec-Feb) will have a start date of 2021-12-01 and an End Date of 2022-02-28.

15. Change the **transparency** to enhance the value color scheme to better see the results. On the top right of the map, move the opacity slider  up to 100% Opaque.

16. Click on **Get Map Layer**, wait for the map to load. The loading of the map may take a few minutes for the request to process.

17. Zoom into the **Navajo Nation Mountain Ranges** for **Chuska Mountain** using the "+" sign along the top right. Bring the Chuska Mountain boundary to center map.
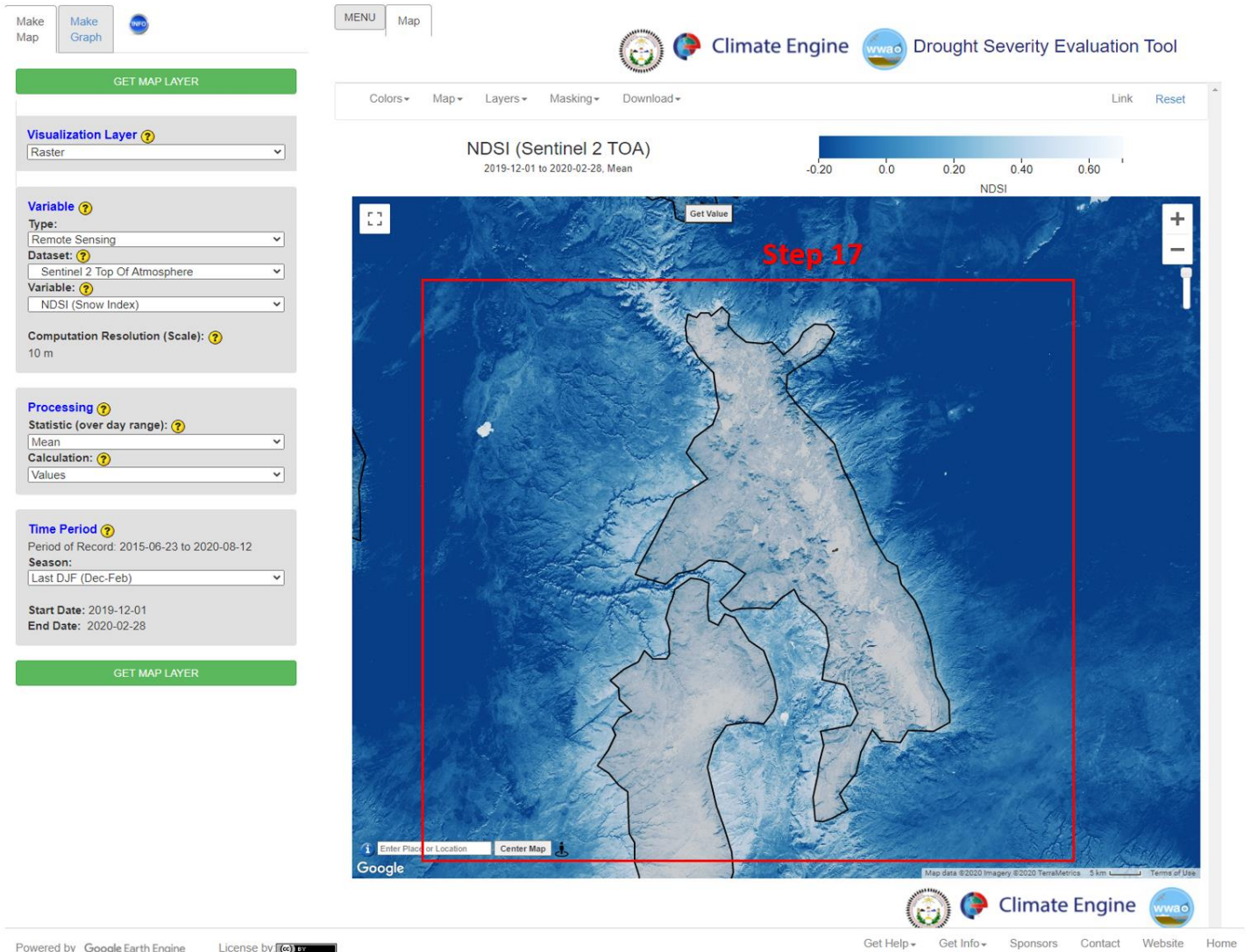
Figure 3. Following the instructions of Step 17 the Chuska mountain range brought to center map.

18. **Do not Reset**. We will use the findings from Case Study 3: Wildfires and Climate Sensitivity of Meadows, which examined BAI values with the Asaayii Lake Fire, in this next section.

## Part 2: Chuska Mountain Snowpack Time Series

- Objective: Create a time series of SWE and NDSI values for Chuska Mountains for the Last December, January, February (DJF) time period (2019 – 2020).

This section of the case study is intended to look at multiple variables for snowpack over a short time period for the Chuska Mountains. The Chuska Mountains remains a region

that receives the majority of the total winter snowpack. SWE and NDSI will indicate patterns of snow density and cover.
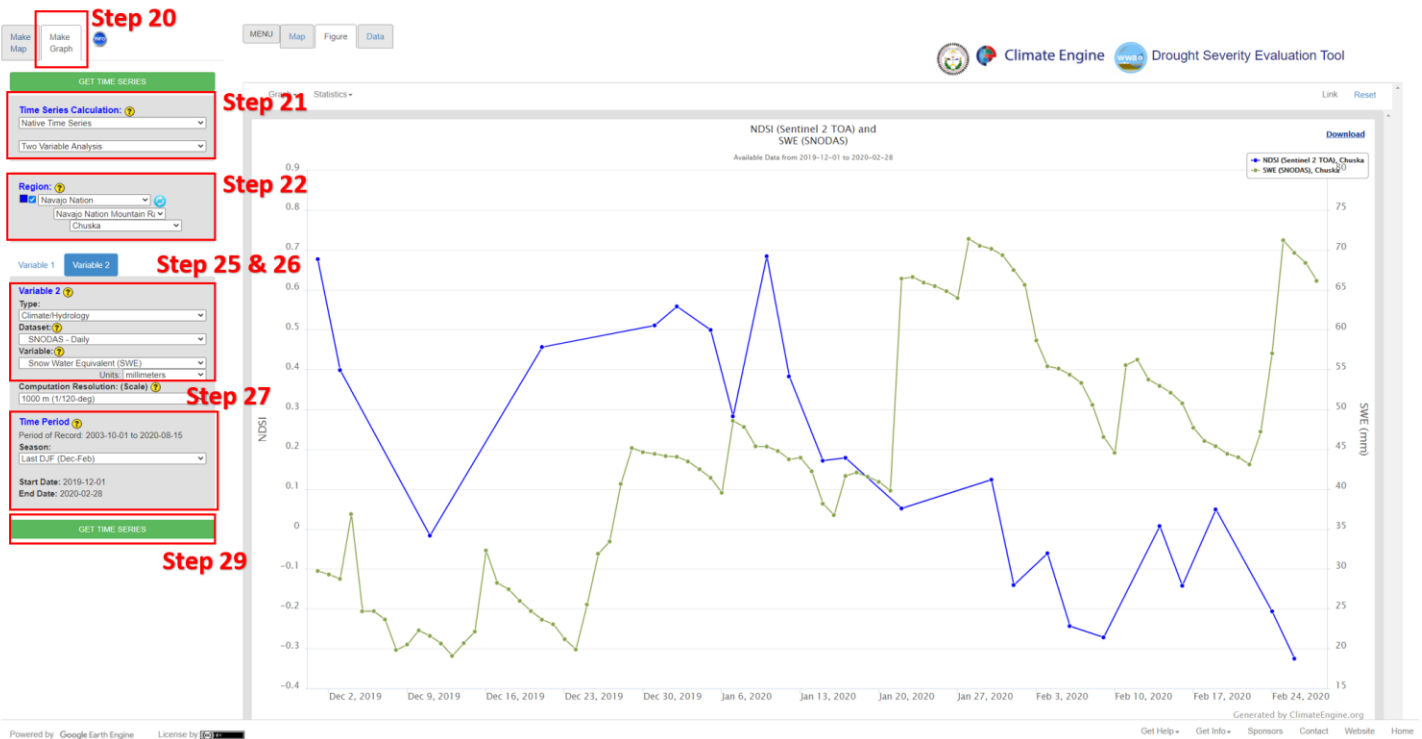


Figure 4. SWE and NDSI value comparison for the Last DFJ for the Chuska Mountain. NDSI values in this figure represent the snow cover and SWE indicates the volume of water stored in the snowpack. Steps 20-29 are included on this figure to help navigate to the DSET features to complete this case study.

19. Leave the **Make Map** panel as is from Part 1 of this Case Study.
20. Click on **Map Graph** tab beside the **Make Map** tab along the top left section of the DSET home screen.
21. Under **Time Series Calculation** leave the first drop-down on **Native Time Series**. Change the second drop-down as **Two Variable Analysis.**
22. Under **Region** select **Navajo Nation**, under the second drop-down select the **Navajo Nation Mountain Ranges**, and finally under the third drop-down select **Chuska**.
23. The **Variable 1** section can be left as is with the selected **Type, Dataset, and Variable**.
24. Click on **Variable 2**, we are adding Snow Water Equivalent (SWE) data to understand the snowpack on the Chuska Mountain.
25. Under **Variable 2** for the **Type** select **Climate/Hydrology.** For the **Dataset** section, select **SNODAS - Daily**.
26. For the **Variable** select **Snow Water Equivalent (SWE)** and leave the units in millimeters.
27. Under the **Time Period** section located on the same panel, select the **Last DJF (Dec-Feb).**

    a. Selecting the **Last DJF (Dec-Feb)** will change the **Start Date** to **2019-12-01** and end date to **2020-02-28**. Depending on the year of analysis the year will change. For example, if this exercise is done in the year 2022, the Last DJF (Dec-Feb) will have a start date of 2021-12-01 and an End Date of 2022-02-28.

28. **Check** to make sure the **Time Period** is the same for **Variable 1** and **Variable 2**.
29. Click on **Get Time Series** and wait for the map to graph.
    a. If your time series does not appear after a few minutes you may have to **Reset** DSET again and run the analysis. Due to the large time frame loading including many years of data this might create some issues.

Figure 4 displays the SWE (in green) and NDSI (in blue) comparisons for the Last DJF. Generally, the two variables display similar patterns of snowpack development over the Chuska Mountains. Early in December 2019, the NDSI values are found to be higher than the SWE values. This higher NDSI values at this time indicates snow covered area. A higher snow-covered area is interpreted as fresh snow fall and the growing intensity of the winter season. By mid-January 2020, the SWE increases, indicating increased accumulation of snowpack during the coldest portion of the winter. This displays the progression of snowfall and snowpack accumulation throughout the winter season where SWE is also increasing after multiple winter storms.

## Additional Resources

- The Applied Remote Sensing Training (ARSET) is a program that is designed to build the capacity of decision-makers to use NASA data. ARSET offers online and in-person trainings for beginners and advanced practitioners alike. Trainings cover a range of datasets, web portals, and analysis tools and their application to air quality, agriculture, disaster, land, and water resources management. http://appliedsciences.nasa.gov/arset

- The National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information provides public access to climate and weather data. This particular link provides a deeper look at drought as well as provide projections: https://www.drought.gov/drought/data-maps-tools/tools

- DSET is a spin-off of Climate Engine, a web-based platform for conducting on-the-fly climate analysis: http://climateengine.org/data